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Original Article

# Treatment of fractures of the tibial diaphysis using external fixator compared with locked intramedullary nails

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*Objective*: To compare efficiency of external fixator in modular form with unilateral and uniplanar intramedullary locked seeking definitive treatment of fractures of the tibia diaphysis. *Methods*: Orthopedic surgical treatments were compared to 50 patients with definite diafisária fracture of the tibia, through the use of the external fixator, modular and intramedullary locked. The fractures were treated at emergency hospital school of Orthopedics and Traumatology service in the period from January 2007 to January 2011, with a variation of 15 to 48 weeks. *Results*: this study has proven functional results and excellent consolidation when locked intramedullary rods were used and the versatility and speed of application of external fixator reaching the necessary stabilization of bony fragments. Consolidation of fractures was obtained in 95 cases when using the intramedullary locked and 90 cases undergoing external fixation. *Conclusions*: the definitive treatment of tibial diaphysis fractures by external fixator modular presented themselves as valid alternative treatment in patients who could not be submitted for early conversion to internal osteosynthesis or when the intramedullary nails are not available to the surgeon.



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## Introduction

Among long-bone fractures, those of the tibial diaphysis occur most frequently. Appropriate treatment methods are needed in order to avoid occurrences of consolidation failure, skewed consolidation and reoperation.[1] Epidemiological studies in Brazil[2,3] have confirmed the high frequency of this type of fracture and have revealed that there is greater incidence among males and in the aged group from 21 to 30 years; that they are frequently associated with traffic accidents; and that most of them are exposed fractures. It has been estimated that the number of deaths due to traffic accidents is around 40,000 in Brazil and 1,300,000 worldwide. Another worrying statistic is that for every death, there are 11 individuals with permanent sequelae, and 38 hospitalizations for every 380 cases of emergency attendance.[4]

Although non-dynamic external fixators are classically provisional methods for treating these fractures, the large number of cases, chaos of public healthcare provision and severity of associated trauma lead to acceptance of modular external fixators in some cases, as a proposal for definitive treatment, i.e. until fracture consolidation has been achieved.

External fixators are fixation devices of greater versatility that make it possible to set up a variety of types of assembly and configurations. They can be placed rapidly and are applied in treatments for fractures in emergency situations (damage control). This is done percutaneously, with less damage to the soft tissues.[5] Independent of whether external fixators are used for the purposes of provisional or definitive treatment, the emergency setup should respect the basic precepts of fracture stabilization and alignment, and insertion of bars and Shanz pins, with attention to safety issues relating to pin and wire insertion at different follow-ups.[6]

The introduction of intramedullary nails has reduced the complications arising from surgical treatment. However, the indications for their use are limited. Only since the advent of locking nails has greater dissemination of their use become possible, through their greater rotational control and greater stability.[7]

Tubular external fixators constitute the treatment method most used for exposed fractures of the tibial diaphysis.[8] External fixators provide good stability for bone fragments; they are versatile, quickly installed and precise, and they can be installed by different teams without technical difficulties. Their use does not give rise to any more than minimal damage to the vascular supply of the tibia and the surrounding soft tissues, and allows other teams such as plastic surgery and vascular surgery teams to undertake interventions. They are also indicated both for exposed fractures and for closed fractures that are associated with high-energy trauma, based on Tscherne's classification. Thus, choosing an external fixator is based on the magnitude of the trauma and the associated soft-tissue injuries, and not just on whether the fracture is exposed or closed.[9]

This study evaluated the results from using modular external fixators arranged in a uniplanar and unilateral form, in comparison with use of locked intramedullary nails, for definitive surgical treatment of fractures of the tibial diaphysis.

## Materials and methods

Fifty emergency cases seen at the emergency service of the teaching hospital of the School of Medicine, Universidade Federal do Triângulo Mineiro (a reference center for orthopedic and traumatological care), between January 2007 and January 2011, were analyzed. Cases were considered to be fractures of the tibial diaphysis if they occurred more than five centimeters below the knee joint and more than five centimeters above the ankle.[2,9] A modular external fixator or a locked intramedullary nail was used, based on the magnitude of the trauma and the condition of the soft tissues involved. Cases in which an external fixator was used were included in the protocol for this study after the external fixator had been in place for more than two weeks, thus establishing it as the definitive treatment. There were no restrictions relating to the patients' social conditions or age. The method for using and indicating modular external fixators or locked intramedullary nails has been standardized in our service, which is an important factor for achieving uniform definitive case management, given that cases would be dealt with by different groups. The outpatient follow-up and postoperative evaluation were performed by a single group, with standardization of the observation criteria.

The mean age of the group was 30.98 years (range: 17 to 65 years), and the majority were in their third decade of life; 38 (76%) were male (Fig. 1); and there were 31 exposed and 19 closed fractures. Among the exposed fractures, Gustilo grade I was the most frequent finding (41.93%), and among the closed fractures, Tscherne type zero predominated (73.64%). The largest proportion of the fractures had a single line (38%), and type A3 (transverse) was the commonest finding.

For all of the patients evaluated (Table 1), their fractures originated in high-energy trauma: accidents with motor vehicles, being run over and falls from a great height. The mean length of follow-up was 15 to 48 weeks, with the exception of one case in which a locked intramedullary nail was used, which consolidated in 96 weeks. It needs to be noted that this patient was differentiated through low educational and socioeconomic level (Figs. 2 and 3).

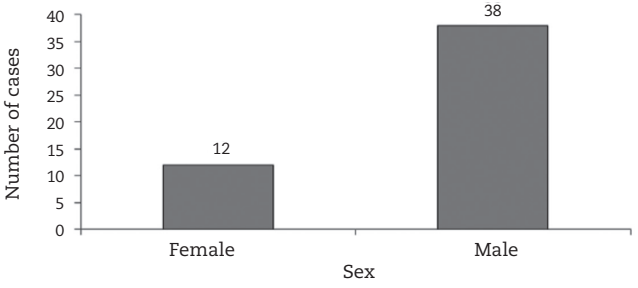


**Fig. 1 - Number of cases according to gender.**

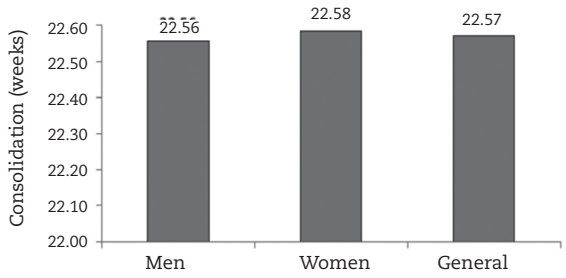


**Fig. 2 - Consolidation in weeks.**

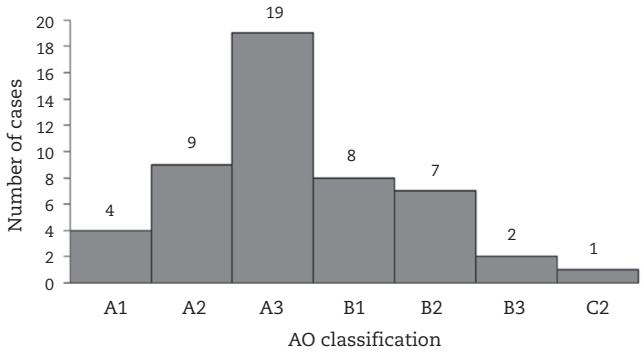


**Fig. 3 - Histogram of frequency of cases according to the AO classification.**

stability of this assembly, we positioned a second longitudinal bar with another four pin-tube connectors.

The radiographic control was performed in the anteroposterior and lateral views, and the whole length of the leg was observed.[12] Most authors[12-14] have accepted occurrences of less than one centimeter of shortening, alignment of 5° to 10° of varus or valgus and, anteroposteriorly, less than 20° of external rotation and 10° of internal rotation. The layout of the basic components of the external fixator box is presented in Fig. 4.

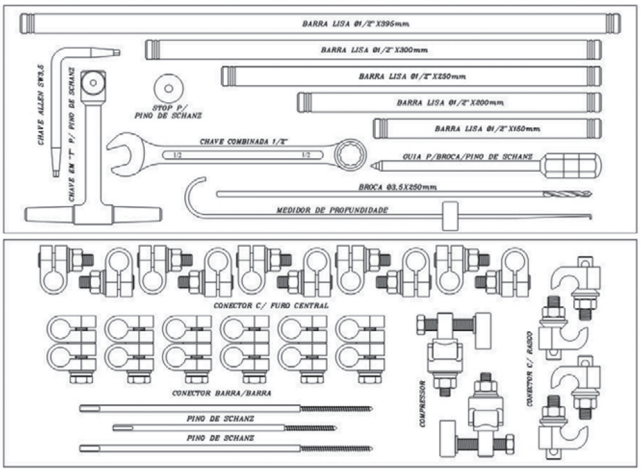


**Fig. 4 - Components of the external fixator box.**

*Initial evaluation*

The patients of this study were evaluated regarding bone exposure and fracture morphology. For exposed fractures, we used the Gustilo classification.[10] Morphologically, the fractures were classified in accordance with the AO method for classifying long-bone fractures.[11] After this evaluation, the patients were sent to the surgical sector for treatment.

*Surgical techniques*

*Modular external fixator*

The surgical technique consisted of positioning Schanz pins in the bone, and the insertion method needed to be the same in every case, performed systematically by the orthopedic team. They were placed by means of a trocar that was introduced into the soft tissues through a percutaneous incision of approximately one centimeter. The trocar had three stages: central – a nail that was used to mark the bone, which avoided slippage of the set; intermediate – this served as a guide for the 3.5 millimeter bit that we used to drill both of the cortical bone layers along the bit path; Schanz pin guide – this was passed manually through the two cortical bone layers (self-tapping). Two Schanz pins were placed in each bone fragment, so as to attain an anatomical reduction, with greater contact between the fragments at the focus of the fracture. To increase the

*Locked intramedullary nail*

Under anesthesia, the patient was positioned in horizontal dorsal decubitus on a radiotransparent table, and an image intensifier was positioned contralaterally to the fractured limb and perpendicularly to the surgical table. A pneumatic tourniquet was positioned at the root of the thigh. Asepsis and antisepsis were performed along the entire lower limb. The fractures were reduced as closed procedures by means of manual traction and manipulation, and a longitudinal incision of six centimeters was made in the infrapatellar region. The patellar tendon was opened longitudinally or moved away laterally and, with the aid of separators, the tibial tuberosity was viewed. Access to the medullary canal was obtained using a sharp-tipped piercing device at the level of the tibial tuberosity and a guide pin with a rounded tip. This pin was inserted into the fracture site, under control through the image intensifier, in order to check its position. Medullary enlargers were progressively inserted until reaching a diameter one millimeter wider than the nail chosen. The guide pin with the spherical tip was removed and one with a smooth tip was introduced. With the aid of the image intensifier and a hammer, the intramedullary nail was introduced. Proximal and distal locking was done with guidance from an external device (template). A 3.5 mm bit was used to drill the holes in which the locking screws would be placed. The cortical screws were also inserted under control through the image intensifier and, before inserting the locking screws, correct rotational

**Table 1 - Distribution of the patients studied.**

| Patient | Sex | Age (years) | Gustilo | Tscherne | AO classification | External fixator | Locked intramedullary nail | Time taken for consolidation (weeks) |
|---|---|---|---|---|---|---|---|---|
| 1 | M | 37 | IIIA | | A2 | X | | 33 |
| 2 | M | 20 | I | | A2 | X | | 16 |
| 3 | M | 19 | II | | A2 | X | | 22 |
| 4 | F | 37 | II | | A2 | X | | 23 |
| 5 | F | 32 | I | | B1 | X | | 25 |
| 6 | M | 42 | II | | B1 | X | | 26 |
| 7 | M | 26 | | 2 | B2 | X | | 15 |
| 8 | M | 23 | II | | A3 | | | 20 |
| 9 | M | 22 | II | | B1 | X | | 26 |
| 10 | F | 42 | II | | B2 | X | | 25 |
| 11 | M | 18 | I | | A1 | X | | 16 |
| 12 | M | 19 | I | | A3 | X | | 17 |
| 13 | M | 32 | I | | A3 | X | | 18 |
| 14 | M | 35 | IIIA | | C2 | X | | _ |
| 15 | M | 47 | IIIA | | B3 | X | | _ |
| 16 | M | 23 | IIIA | | B1 | X | | 28 |
| 17 | F | 26 | I | | A3 | X | | 19 |
| 18 | M | 36 | IIIA | | B3 | X | | 30 |
| 19 | M | 27 | I | | A1 | X | | 20 |
| 20 | M | 25 | II | | A3 | X | | 18 |
| 21 | M | 28 | I | | B2 | X | | 25 |
| 22 | F | 28 | I | | A3 | X | | 18 |
| 23 | M | 24 | I | | A3 | X | | 19 |
| 24 | M | 29 | IIIA | | B1 | X | | 29 |
| 25 | F | 34 | IIIA | | B2 | X | | 32 |
| 26 | F | 30 | I | | B1 | X | | 27 |
| 27 | F | 27 | II | | B2 | X | | 28 |
| 28 | M | 25 | I | | A3 | X | | 21 |
| 29 | M | 35 | II | | B2 | X | | 26 |
| 30 | M | 29 | IIIA | | A3 | X | | 25 |
| 31 | M | 35 | | 0 | A3 | | X | 18 |
| 32 | M | 33 | I | | A3 | | X | 16 |
| 33 | M | 20 | | 0 | A2 | | X | 16 |
| 34 | F | 53 | | 1 | A3 | | X | 20 |
| 35 | M | 65 | II | | A1 | | X | 18 |
| 36 | M | 19 | | 0 | B2 | | X | 21 |
| 37 | M | 29 | | 0 | A2 | | X | 18 |
| 38 | M | 23 | | 1 | A3 | | X | 16 |
| 39 | F | 56 | | 0 | A3 | | X | 18 |
| 40 | M | 37 | | 0 | B1 | | X | 20 |
| 41 | M | 42 | | 0 | A2 | | X | 17 |
| 42 | M | 49 | | 1 | A3 | | X | 96 |
| 43 | M | 26 | | 0 | A3 | | X | 20 |
| 44 | F | 17 | | 0 | B1 | | X | 20 |
| 45 | M | 23 | | 1 | A2 | | X | 18 |
| 46 | M | 20 | | 0 | A1 | | X | 15 |
| 47 | M | 48 | | 0 | A3 | | X | 19 |
| 48 | M | 36 | | 0 | A3 | | X | 16 |
| 49 | M | 31 | | 0 | A2 | | X | 18 |
| 50 | F | 27 | | 0 | A3 | | X | 16 |

alignment was obtained and final adjustments were made to the fracture reduction. These were locked statically and did not receive dynamization. The patients received prophylactic doses of cefalotin (2 g) at the time of induction of anesthesia, followed by 1 g every six hours, for 72 hours.

*Postoperative period*

During the immediate postoperative period, the treated lower limb was positioned in a Braun splint in order to keep it elevated, and dressings were placed on the soft-tissue injuries every day. The patient was kept in hospital, under appropriate analgesia and broad-spectrum intravenous antibiotic therapy for three days. During this period, the physiotherapy team started the functional rehabilitation with early passive mobilization and muscle strengthening exercises on the injured limb. When possible, the patient was encouraged to stand upright with the aid of underarm crutches. At the end of three days without intercurrences, the patient was released from hospital and the treatment was completed through outpatient return visits.

The patients who received an external fixator were instructed to take care of the wounds of the Schanz pins by means of daily cleaning, with removal of secretions and crusts. While having baths or showers, patients were recommended to wash the entire limb and external fixator with soap and water. For the patients who received a locked intramedullary nail, dressings were done by a specialized team at an outpatient return visit one week later. At this return visit, subjective criteria (patients' complaints) and objective criteria were evaluated; the latter included assessments on soft-tissue conditions, wounds, joint mobility, limb alignment and external fixator stability. Radiological control was achieved by means of anteroposterior and lateral radiographs on the affected leg, to view whether there had or had not been any loss of reduction in comparison with the radiographs of the immediate postoperative period and to view the stage of consolidation (Figs. 5 and 6). In cases with an external fixator, if any loss of reduction was seen, the positions of the bone fragments could easily be altered through loosening the connections and manipulating the segments. Cases without abnormalities and cases that were satisfactorily manipulated would be kept under outpatient follow-up with clinical and radiographic assessments, and loading on the limb would be progressively allowed.

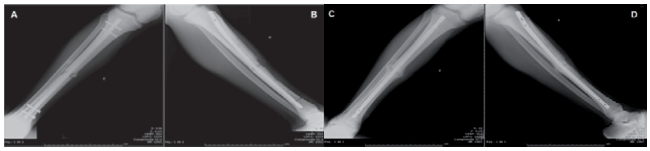


**Fig. 5 - Radiographic images relating to patient number 32, who received a locked intramedullary nail with satisfactory treatment. A and B – Radiographic images on the first postoperative day with a locked intramedullary nail in the tibia for an exposed fracture of the tibial diaphysis that had initially been treated with an external fixator for five days. C and D – Radiographic images produced 18 weeks after the operation, with consolidated fracture of the tibial diaphysis.**

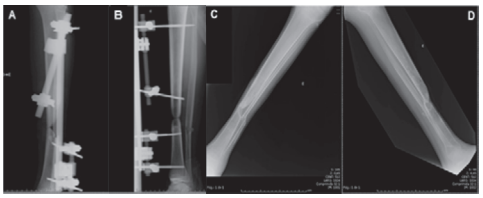


**Fig. 6 - Radiographic images relating to patient number 16, who received satisfactory definitive surgical treatment with an external fixator. A and B – Radiographic images from the immediate postoperative period, in AP and lateral views, respectively, of a fracture of the tibial diaphysis treated with an external fixator. C and D – Radiographic images produced 28 weeks after the operation in AP and lateral views, respectively, of a consolidated fracture of the tibial diaphysis treated with an external fixator.**

## Results

To analyze the results after treatment in the groups with external fixators and locked intramedullary nails, we used the parameters proposed by Paley et al.[15] The results were objectively assessed, with regard to joint movement, muscle strength and bone alignment. Patients gave their opinions about the results, from a subjective point of view, expressing their views about the quality of their return to their activities before the trauma (Chart 1).

Among our patients, 30 were treated with external fixators that were maintained as the definitive treatment and 20 were treated with locked intramedullary nails. Thirty-one cases presented exposed fractures (among which locked intramedullary nails were only used in two cases) and 19 cases were of closed fractures. Of these, three patients evolved with delayed consolidation and, in view of the absence of signs of consolidation (two patients with external fixators and one with a locked intramedullary nail), the external fixation was

**Chart 1 - Paley parameters.**

**Bone result:**
*Excellent* – For cases in which bone union occurs, infection is cured when present, deformity in the axial direction is less than 7° and discrepancy between the limbs is less than 2.5 cm.
*Good* – For cases in which bone union occurs, but one of the other criteria is not attained.
*Fair* – For cases in which bone union occurs, but two of the other criteria are not attained.
*Poor* – For cases in which bone union has not occurred after a period of more than two years.

**Functional result:**
*Excellent* – Cases in which the patients return to their activities without pain, claudication, soft-tissue dystrophy or joint limitation.
*Good* – Cases in which the patients return to their activities, but presenting one of the sequelae above.
*Fair* – Cases in which the patients return to their activities, but presenting more than one of the sequelae above.
*Poor* – Cases in which the patients do not return to their activities before the trauma.

replaced with osteosynthesis using a plate and bone graft after 34 weeks, while the locked intramedullary nail was maintained until consolidation was achieved in the 26th week and was removed in the 32nd week.

In two patients who received locked intramedullary nails, we had to remove the distal screws because an inflammatory process began. The remaining 47 fractures (94%) evolved to consolidation within a period of 15 to 33 weeks, with a mean time taken to achieve consolidation of 23.10 weeks for the patients who received external fixation: in 20 cases (66%), excellent bone consolidation was achieved; in six (20%), good consolidation; in two (7%), fair results; and in two (7%), poor results (Table 2).

In the cases in which a locked intramedullary nail was used, the time taken to achieve consolidation ranged from 15 to 21 weeks, with a mean of 17.89 weeks: in 18 cases (90%), excellent bone consolidation was achieved; in one case (5%), good consolidation; in one case (5%), fair results; and there were no poor results (Table 2). The main functional sequelae were pain and claudication, especially after long periods in an upright standing position.

Regarding the functional results from using an external fixator (Table 3), they were excellent in 13 cases (43%), good in 10 (33%), fair in three (10%) and poor in four (14%) who were unable to return to their preoperative activities. Two of them presented neurological sequelae relating to the initial trauma and the other two did not evolve to consolidation.

In the cases that received a locked intramedullary nail, the functional results were: 17 (85%) excellent, two (10%) good and only one (5%) fair. This last patient presented pain when walking (Table 3).

In the statistical analysis, which compared the use of external fixators and locked intramedullary nails, it was found that the mean number of weeks needed to achieve consolidation was smaller when nails were used. Despite this difference, the statistical analysis showed that external fixators had good results (Table 4).

**Table 2 - Results obtained regarding bone consolidation.**

| Result | External bone fixator | Locked intramedullary nail |
|---|---|---|
| Excellent | 20 (66%) | 18 (90%) |
| Good | 6 (20%) | 1 (5%) |
| Fair | 2 (7%) | 1 (5%) |
| Poor | 2 (7%) | 0 (0%) |

**Table 3 - Functional results.**

| Functional result | External fixator | Locked intramedullary nail |
|---|---|---|
| Excellent | 13 (43%) | 17 (85%) |
| Good | 10 (33%) | 2 (10%) |
| Fair | 3 (10%) | 1 (5%) |
| Poor | 4 (14%) | 0 (0%) |

**Table 4 - Statistical analysis comparing the results regarding time taken for consolidation and patients' ages, in treatment with an external fixator in relation to treatment with a locked intramedullary nail.**

| | Time taken for consolidation (weeks) | | Patients' ages | |
|---|---|---|---|---|
| | External fixator | Locked intramedullary nail | External fixator | Locked intramedullary nail |
| Mean | 23.11 | 17.90 | 28.40 | 33.68 |
| Standard error | 0.96 | 0.40 | 1.25 | 3.14 |
| Median | 24 | 18 | 27.50 | 31 |
| Standard deviation | 5.10 | 1.76 | 6.65 | 13.69 |
| Variance of the sample | 26.03 | 3.10 | 44.17 | 187.45 |
| Interval | 18 | 6 | 24 | 48 |
| Minimum | 15 | 15 | 18 | 17 |
| Maximum | 33 | 21 | 42 | 65 |
| Count | 28 | 19 | 28 | 19 |
| Confidence level (99%) | 2.67 | 1.16 | 3.48 | 9.04 |
| Confidence interval for the mean number of weeks | 22.14 to 24.07 | 17.44 to 18.30 | 27.14 to 29.65 | 30.54 to 36.83 |

## Discussion

Use of external fixators meets the needs of orthopedists working in emergency services, particularly because they are quickly installed, without great complexity, do not require subspecialists, fluoroscopy or special materials, and are highly versatile. In this manner, when used in emergency units that have physicians at different stages of training, iatrogenic lesions become less likely.

Muller et al.[16] defined rigid external fixators as intermediate methods for fracture treatment. However, we had to maintain external fixators as the definitive treatment in some cases because of the large number of patients, occurrences of associated severe trauma and difficulties in obtaining places in the surgical sector, which made early conversion of all the external fixators into internal osteosynthesis impossible. Indications for using external fixators come both from the severity of the soft-tissue injuries and from the patient's clinical condition on arrival, especially with regard to the presence of other injuries, such as cranioencephalic trauma, pulmonary contusion, hemorrhage and lesions of abdominal organs. In such cases, modular external fixators are especially justified, along with maintaining them as the definitive treatment method.

Although the ideal treatment for fractures of the tibial diaphysis in these situations would be early conversion to internal osteosynthesis (intramedullary nail), the circumstances do not always allow this approach. In our study group, it was noted that the evolution of the fractures was

favorable, thus demonstrating that the option of maintaining the modular external fixator was valid.

Ferreira et al.[17] made reference to the study by Court-Brown et al.[18] and argued that using an external fixator could cause esthetic, social, family, professional and psychological problems. They also alleged that, because of the anatomy of the tibia, stabilization is made more difficult through using uniplanar fixators, in that fixation with greater numbers of rods and pins is needed, thus increasing the likelihood of infection.

Brum[6] explained that despite the diversity of results that might be obtained using the external fixation method, this still continues to be the method most used among Brazilian orthopedists in cases of provisional or definitive treatment in emergency situations.

Use of intramedullary nails for treating long-bone fractures, including in the tibia, along with the technical improvements obtained through development of locking nails, has influenced the development of more recent studies. It is important to emphasize that use of locking nails enables early full weight-bearing for patients, thereby leading to faster rehabilitation.[17]

Insertion of proximal and distal locking in the nails has also enabled almost complete weight-bearing as early as the immediate postoperative period, since these are stable fractures. The nails can be used with or without milling of the medullary canal, without any observed differences in the time taken to achieve consolidation or the incidence of infection.[17]

Use of proximal and distal locking in conjunction with intramedullary nails gives rise to good results that are undoubtedly effective, with low morbidity and low incidence of deviation, consolidation failure, joint stiffness and infection.[19]

In a study on treatment of exposed fractures of the tibia in Brazil, Balbachevsky et al.[20] explained that although using locked intramedullary nails for stabilizing these fractures achieved better results, the high costs, inherent technical difficulties and unavailability of equipment in emergency situations limit the applicability of this method. Hence, methods such as external fixation remain among the ones most used.

In comparing the data of the present study, it was noted that among the patients who received an external fixator, two (7%) needed to be reoperated; 12 (40%) presented superficial infection at the pin insertions and operative wound and nine (30%) presented skewed consolidation. Among the patients who received intramedullary nails, one (5%) evolved with delayed consolidation; two (10%) presented inflammatory processes at the distal screws; 19 (95%) presented consolidation; 18 (90%) evolved with excellent consolidation and 17 (85%) evolved with an excellent functional result, according to the Paley criteria.

Definitive treatment with an external fixator presents effective results and becomes a treatment option when the circumstances do not allow conversion of these external fixators into internal osteosynthesis.

## Conclusion

Use of locked intramedullary nails is an effective and low-risk treatment, and it has been shown to be the preferred treatment for fractures of the tibial diaphysis, both for the initial treatment and for conversion from an external fixator later on. As a definitive treatment for fractures of the tibial diaphysis, modular external fixators attain good bone consolidation rates and are a valid treatment option for patients who cannot undergo early conversion to internal osteosynthesis, or when the nails are unavailable to the surgeon. The Schanz pin insertion technique and the stabilization obtained are critical factors for the possibility of maintaining the external fixator as the definitive treatment. Installation of an external fixator in the tibia is easily and rapidly performed, and does away with the need for fluoroscopy, special materials and presence of subspecialists.

## Conflicts of interest

The authors declare that there was no conflict of interests in conducting this study.

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